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RESEARCH ON A WEB GIS-BASED GPS VEHICLE MONITORING SYSTEM

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ABSTRACT

We present recent research focused on the construction of a Web GIS-based GPS vehicle monitoring system to locate or navigate thousands of vehicles simultaneously.

Keywords: GIS, Network transmission efficiency, Computational efficiency, Location monitoring, GPS, Vehicle monitoring

As a part of the electronic, government-oriented, geographic information service system, a Web GIS-based GPS vehicle monitoring system not only enables the government to make decisions for traffic control and to implement dynamic vehicle management with a higher efficiency and a lower cost, but also provides the public with real-time access to positioning information and administrative information without any expense.

Table 1. The characteristics of three different models of system foundation

Construction mode		**System stability**	**Multi-Access difficulty**	**Installation complexity**	**Upgrade cost**	**Running speed**	**Network transmitted data volume**	
							Map data	**Positioning data**
C/S		medium	medium	high	high	medium	low	high
stand-alone system		high	high	medium	medium	high	naught	naught
B/S	**Fat client**	high	low	low	low	medium	low	high
	Slim client	high	low	low	low	low	high	high

Compared with other models, despite some flaws, the fat-client B/S model has three decisive advantages, especially for a commercial system.

A. Accessibility - the only requirement for all end users is access to the Internet.
B. Installation convenience - the system can run on any type of Internet browser, such as IE and Firefox, which is the basic part of most operating systems nowadays. In fact, there is no installation work for the client, whether the number of the users is 1 or 10,000 or more.
C. Extensibility - when the monitor system is upgraded, the only need is to update the program at the server.

However, in the course of developing such a system, two major challenges appear:

1. Network bandwidth is the bottleneck because both geographic maps and vehicle positioning data in the system are massive, and they need to be transmitted frequently.
2. A rational assignment of the computational work rationally between the client and the server is a big problem also. In fact, this is partly associated with the first problem. If the computational assignment is determined, the data required to be delivered can be assessed. The uncorrelated part is that when multiple-accesses occur, the computational task will increase in a geometric progression on the server's side.

To solve these problems, our approach contains components as follows:

First, a three-tiered architecture of B/S pattern with a fat client is adopted as the system framework. The client software (downloaded java applet) implements most of the computational work including zoom in, zoom out, centering the particular vehicle on the map, and so on. The servers are divided into three groups: the positioning data servers are in charge of storage and reception of positioning data; the map data servers are responsible for storage of geographic maps and data delivery; and the business servers are mainly for data processing and implementation of business logic. The system deployment configuration is shown in Figure 1.

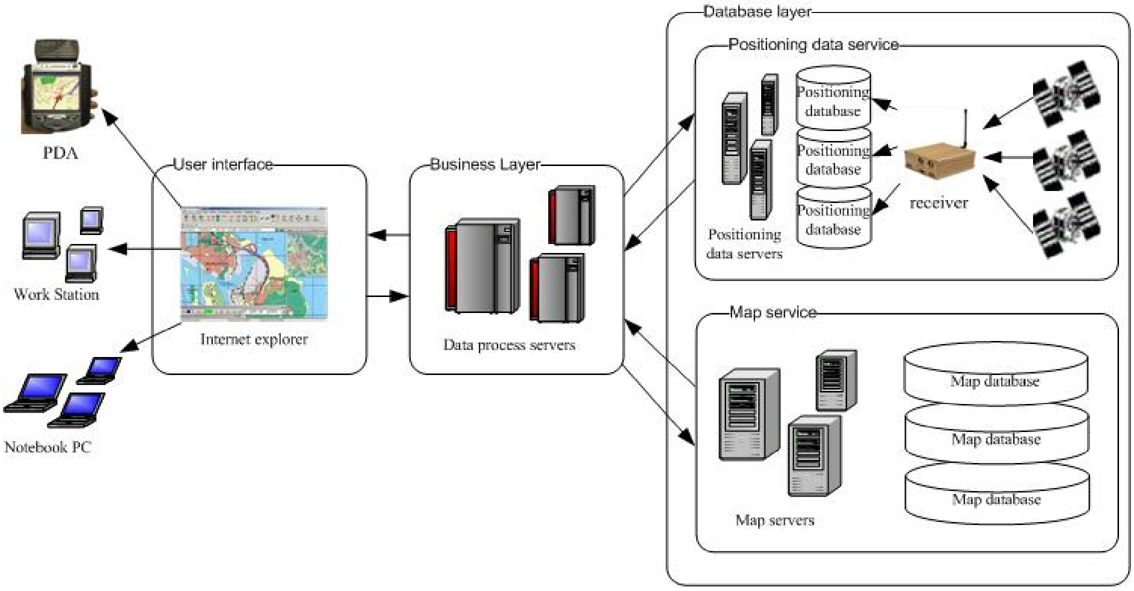

Figure 1. System deployment configuration

Next, we alter the organizational pattern of geographic maps into a hierarchical pyramid structure. The map of the smallest scale is divided into four map sheets, each map sheet is mapped to a larger scale map, and spatial indices are set up between map sheets of different scales. The process iterates until the volume of the map sheet is under a specified threshold. In the small scale map, all unnecessary details are abandoned (Figure 2).

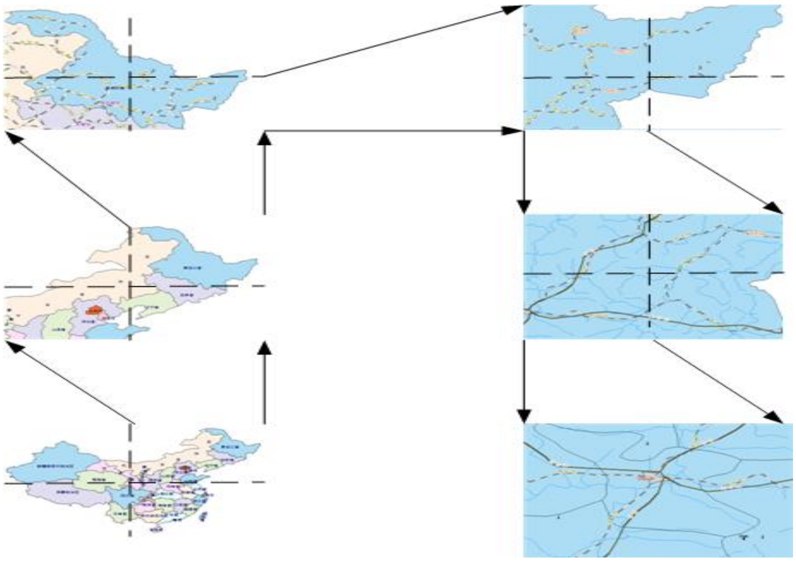

Figure 2. An example of the hierarchical map structure, with each scale being reduced by a factor of four

When the system initiates, the map is viewed in the smallest scale, the outline of the country (lower left in Figure 2). When the scale is magnified, the border of the vision field is sent to the map server. Its response includes a more detailed layer, with a volume no more than the threshold, to place over the outline layer. In this way, dynamic map downloading is realized, and the transmitted data volume is greatly reduced.

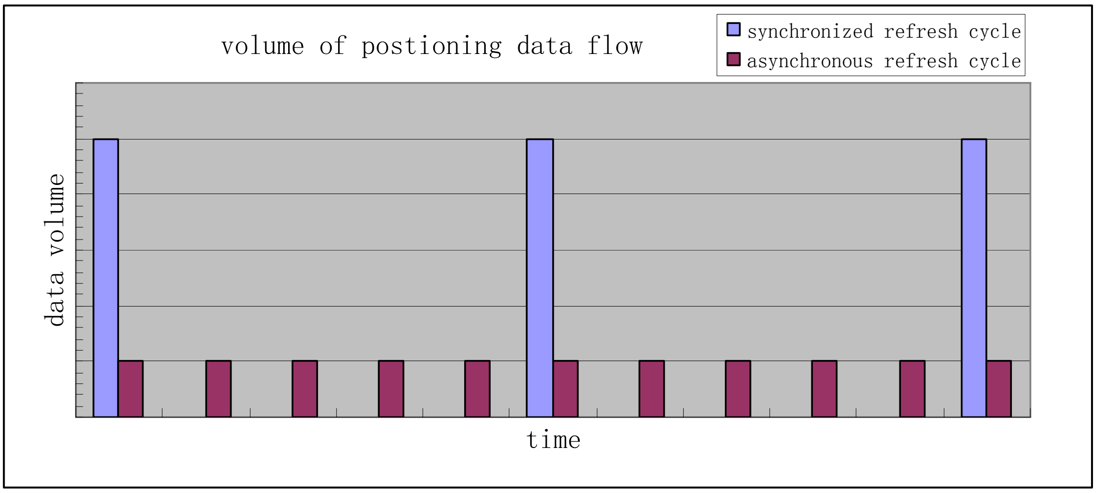

Figure 3. Relative volume of data flow for synchronous and asynchronous refresh cycle

The third step transmits the positioning data asynchronously. Classically, the client will simultaneously send a request for all vehicles' positioning data after a refresh cycle. As a result, the network idles for a long period of time and jams for a small period. If we stagger the refresh cycle, then the network load becomes even. The action to locate one vehicle need not wait for the entire data set (Figure 3).

The fourth step, the refresh frequency, which obtains the latest positioning data from the server at runtime, is auto-adjusting according to the scale of the map. This decision is based on the fact that from the viewpoint of users, a long distance on a small scale map is not as noticeable as on a large scale one. For example, when the smallest map is shown, all vehicles are in the range of the vision field. If the refresh frequency is fixed at ten minutes, even when we deliver the positioning data asynchronously, there will be hundreds of coordinate pairs needed to transmit in one second. But a vehicle with an average rate of 80 km/h only moves one or two pixels per hour on the screen. Therefore, it is reasonable to set the refresh frequency at five hours or more, and then the per second network load will be no more than ten coordinate pairs.

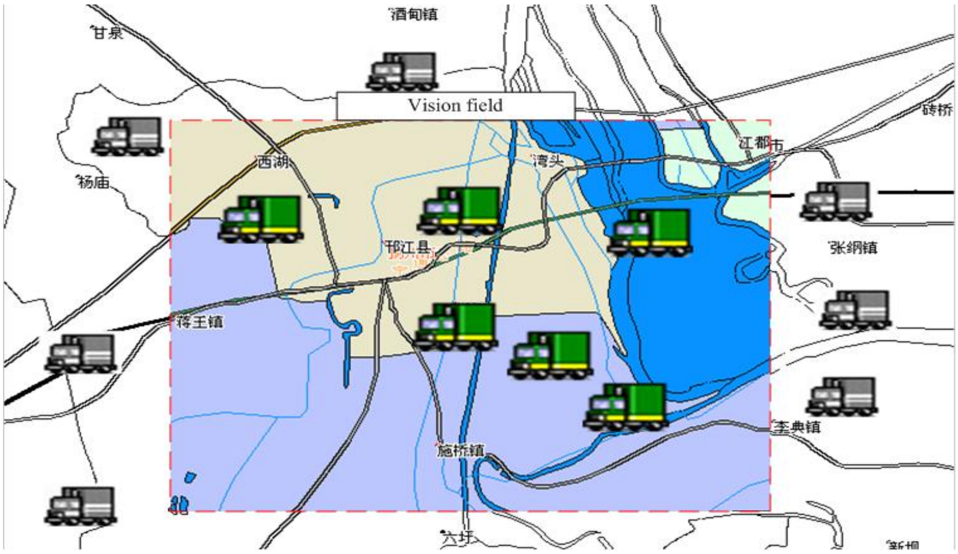

Figure 4. The system transit data only on vehicles within the vision field (shaded area)

The fifth step is that the positioning data server only delivers the positioning data of vehicles that are currently in the vision field (Figure 4). This measure is analogous to the third step and adopts similar arithmetic. Compared with transmission of the entire positioning data, sending back the coordinates of the map extent and searching for the required data in the server are more affordable to network bandwidth and the patience of users.

The performances demonstrated in the experiment confirm the validity of these measures. Finally, the system achieves the balance between computational efficiency and transmission speed on internet.

CONCLUSION

Using Web-GIS to implement GPS monitoring is a promising implementation mode for public service and GPS monitoring in big organizations. The critical bottle neck is the bandwidth because both geographic maps and vehicle positioning data in the system are masses, and they need to be transmitted frequently. In this paper, we illustrate five methods to solve this problem. The performances demonstrated in the practice applications confirm the validity of these measures. Finally, the system achieves a balance between computational efficiency and transmission speed on the Internet and gains a nice user experience.